Some Thought on ν_e Appearance Background Study for BNL VLBL and UNO

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_ π^0 Finder — Performance of π^0 finder

_S/N — Status of signal/background

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_ Prospect/plans — Things to be down

_ Conclusions

- How do we find the signal ?
  - **$\nu_\mu \rightarrow \nu_e$ and ν_e+N-> e + N' + (invisible πs)**
  - **Look for single electron events**
  - **Major background**
    - ν_μ + N -> ν_μ + N' + π^0 + (invisible πs)
    - ν_e contamination in beam (typically 0.7%)
  - Initial cut:
    - One and only one electron like ring with energy greater than 100 MeV without any decay electron
  - Likelihood analysis using the following variables:
    - pi0-likelihood, e-likelihood, energy fraction, costh, pi0mass
    - Δ pi0-likelihood, total charge/electron energy

Used variables in ntuple

- **vertex position**
- N_{ring}
- **total charge**
- $N_{decay\ electron}$
- **particle id in form of likelihood: e-like vs mu-like**
- **particle energy and 3-momentum**
- **pi0 likelihoods : forward vs wide, together with energy and 3-momentum of photons**

- interaction mode
- info about primary and secondary particle 4-vector and id

π^0 finder

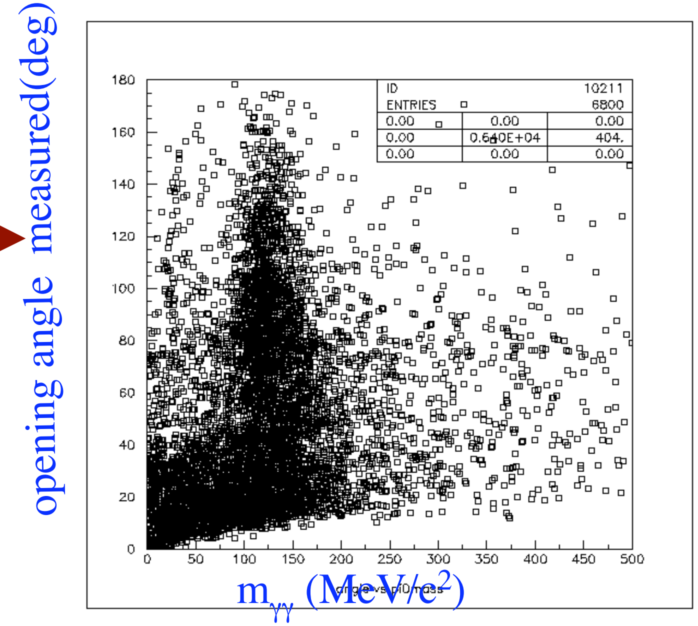
- **π^0 detection efficiency with standard SK software**
- **π^0 detection efficiency with π^0 finder**

Always finds an extra ring in a single ring event

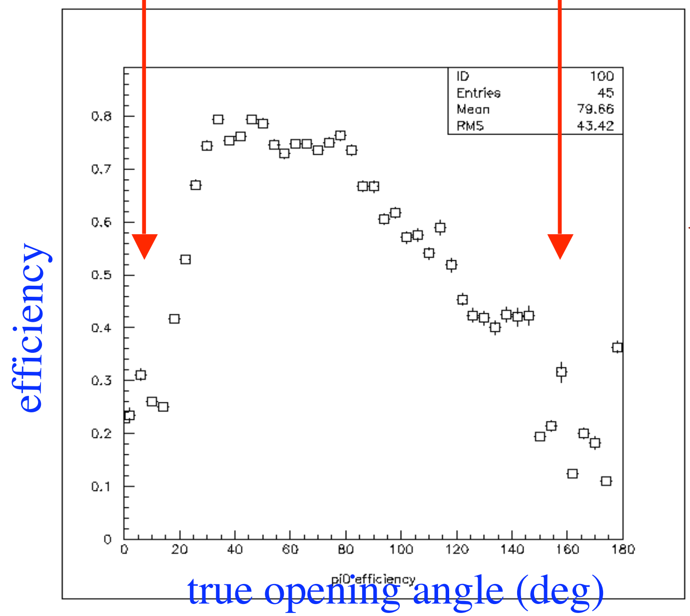
inefficiency
overlap

inefficiency
weak 2nd ring

Single e-like events from single π^0 int.

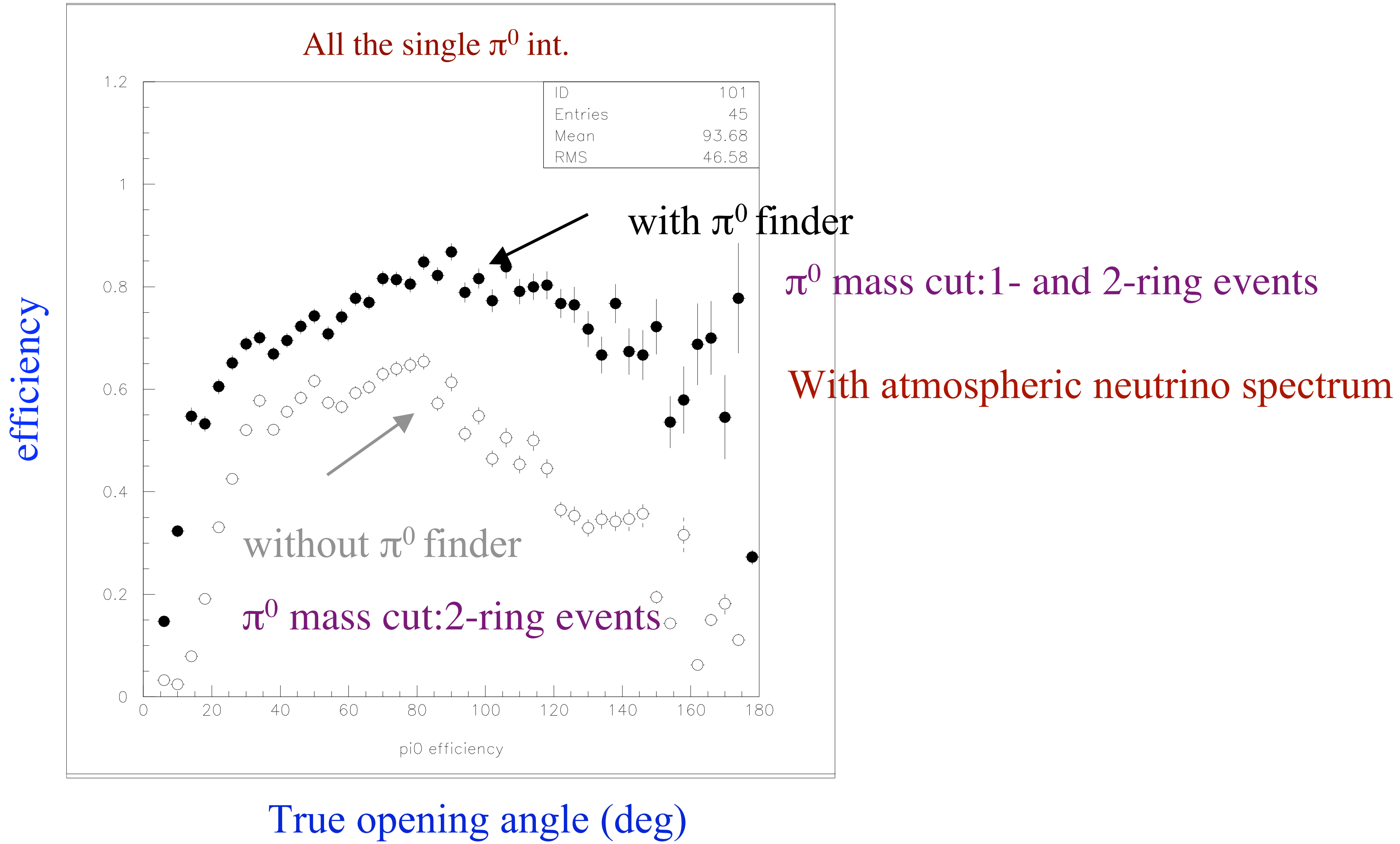


All the single π^0 int.



π^0 finder

- π^0 detection efficiency with standard SK + π^0 finder



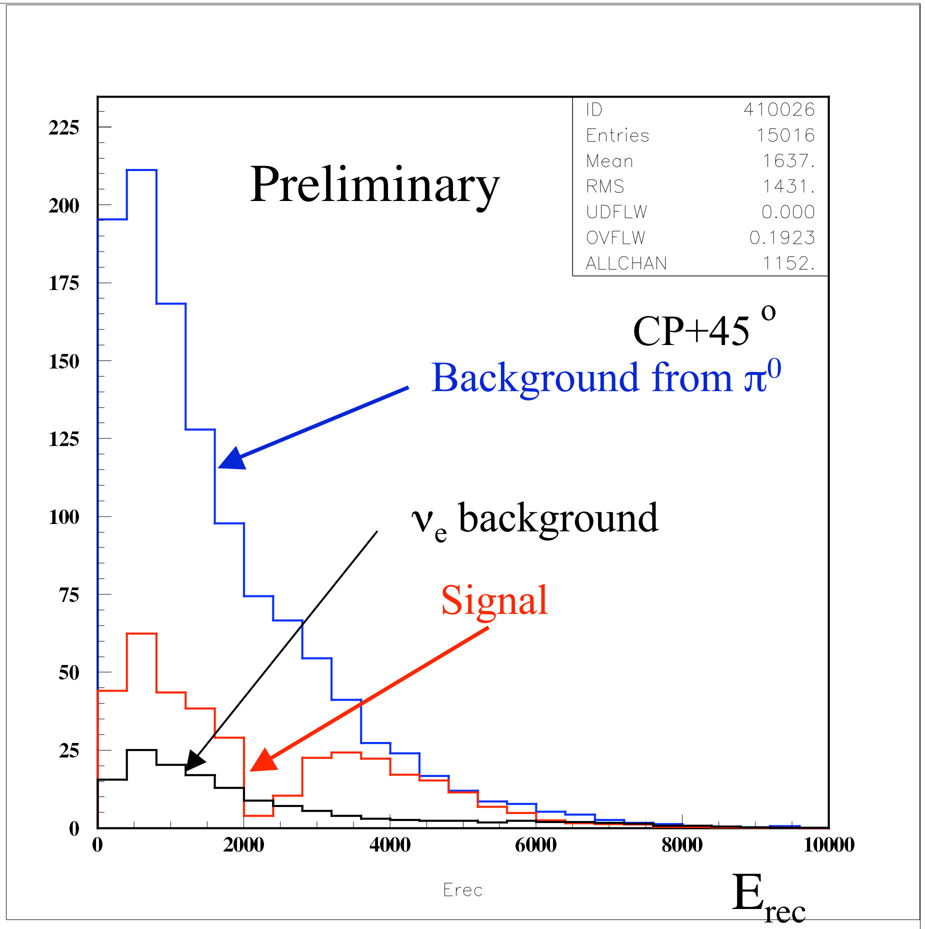
Note new background estimate!

Signal/Background

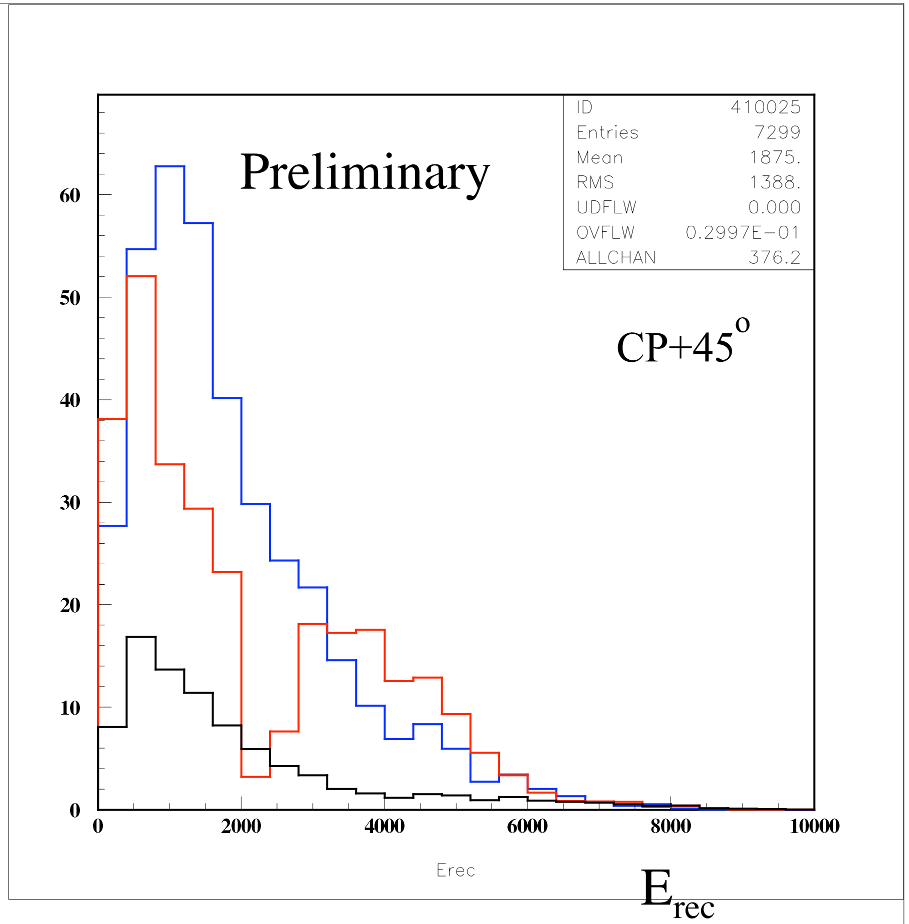
Singnal and Background ν_e QE for signal, all ν_μ and ν_e NC/nonQE CC for bkg

- Effect of cut on Δ likelihood

No Δlikelihood cut (~100% signal retained) Δlikelihood cut (~80% signal retained)



Signal 365 ev Bkgs 1293
(1152 from π^0+others)
(141 from ν_e)



Signal 289 ev Bkgs 463
(376 from π^0+others)
(86 from ν_e)

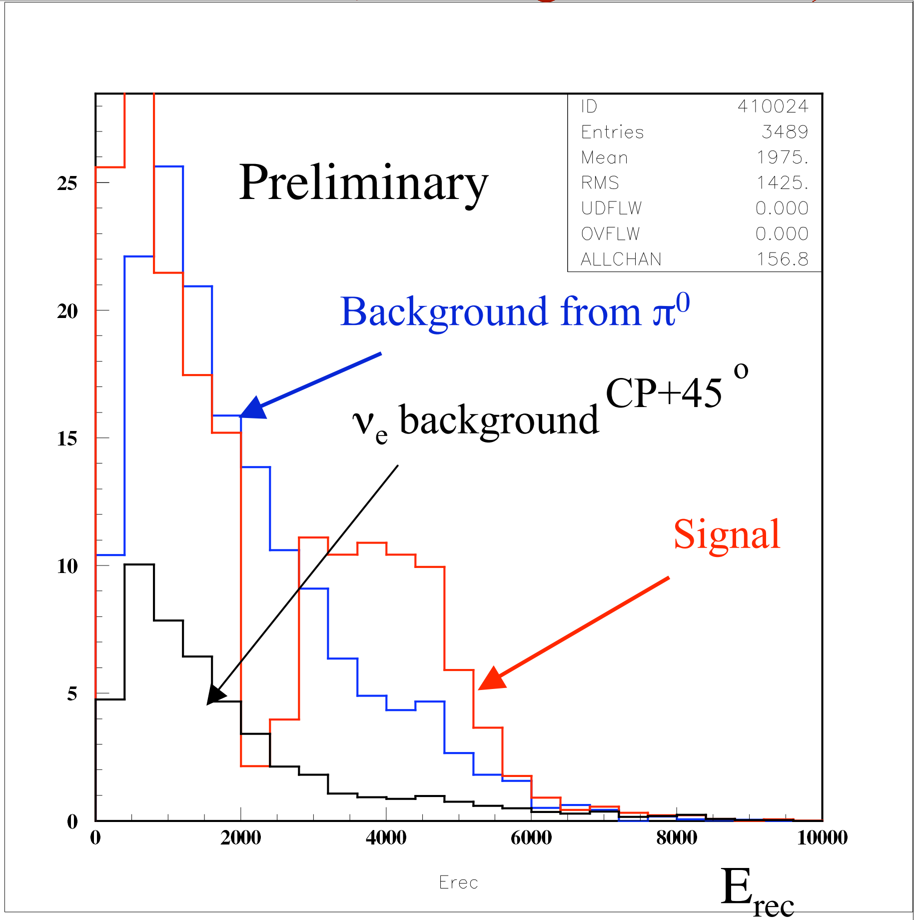
Note new background estimate!

Signal/Background

Singnal and Background ν_e QE for signal, all ν_μ and ν_e NC/nonQE CC for bkg

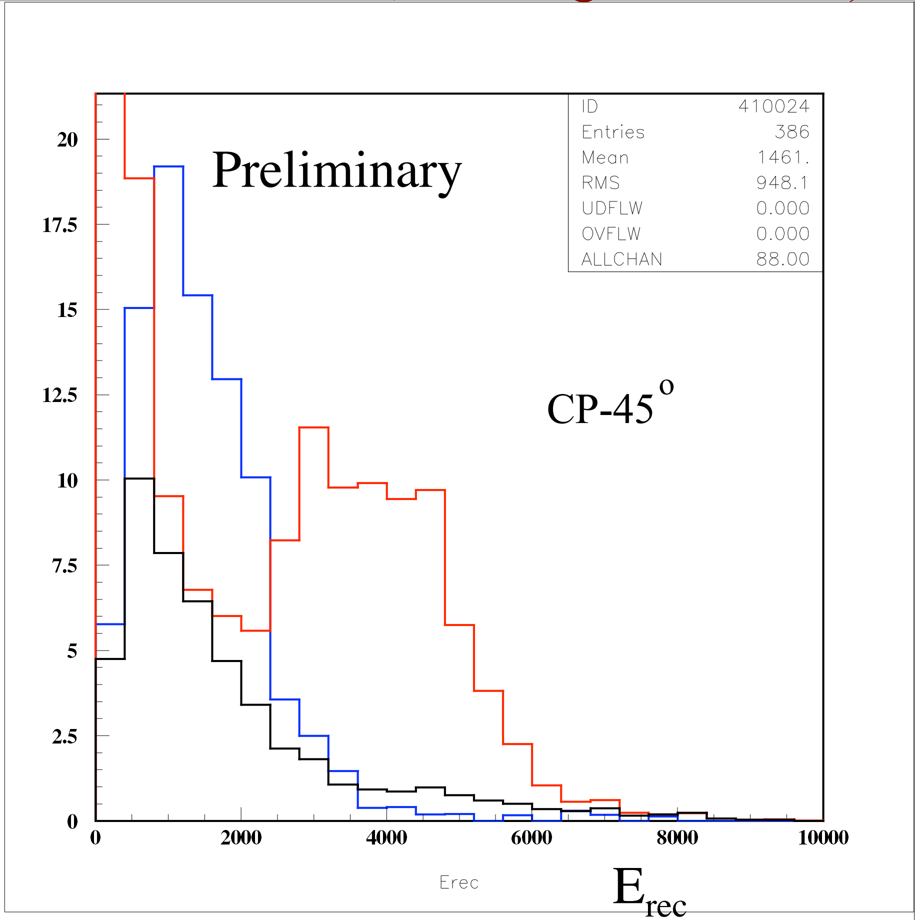
- Effect of cut on Δ likelihood

Δlikelihood cut (~50% signal retained)



Signal 187 ev Bkgs 206
(157 from π^0+others)
(49 from ν_e)

Δlikelihood cut (~50% signal retained)



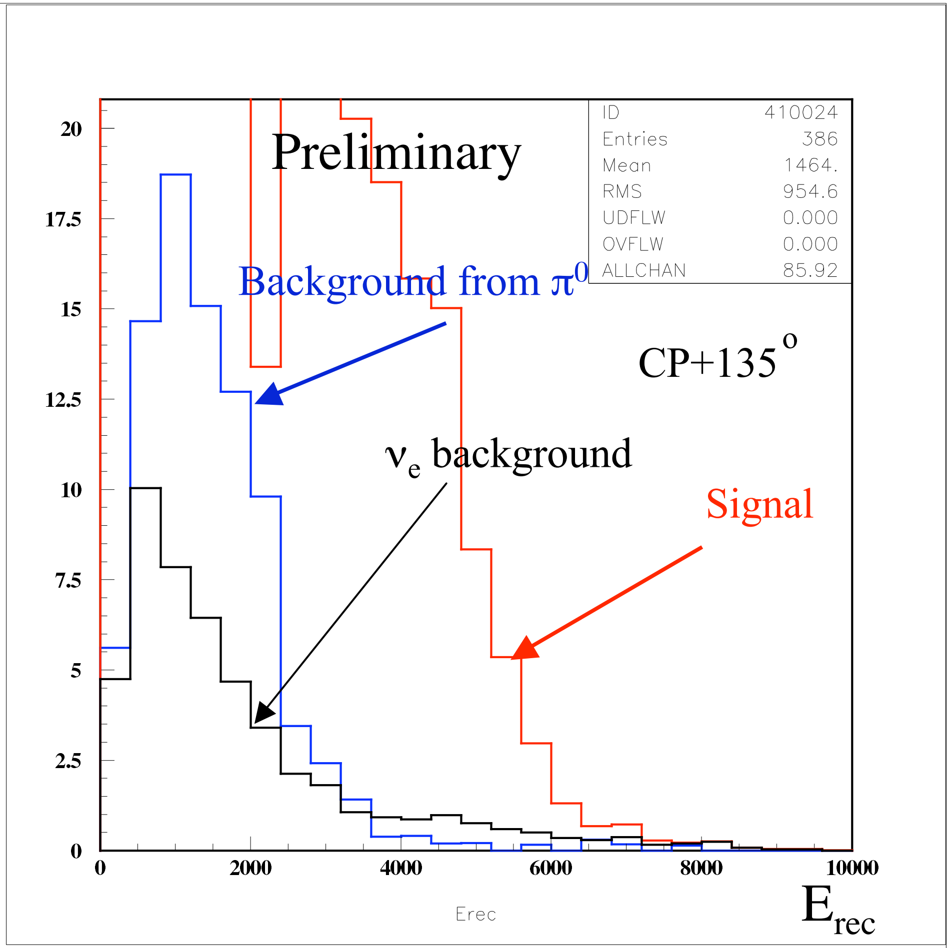
Note new background estimate!

Signal/Background

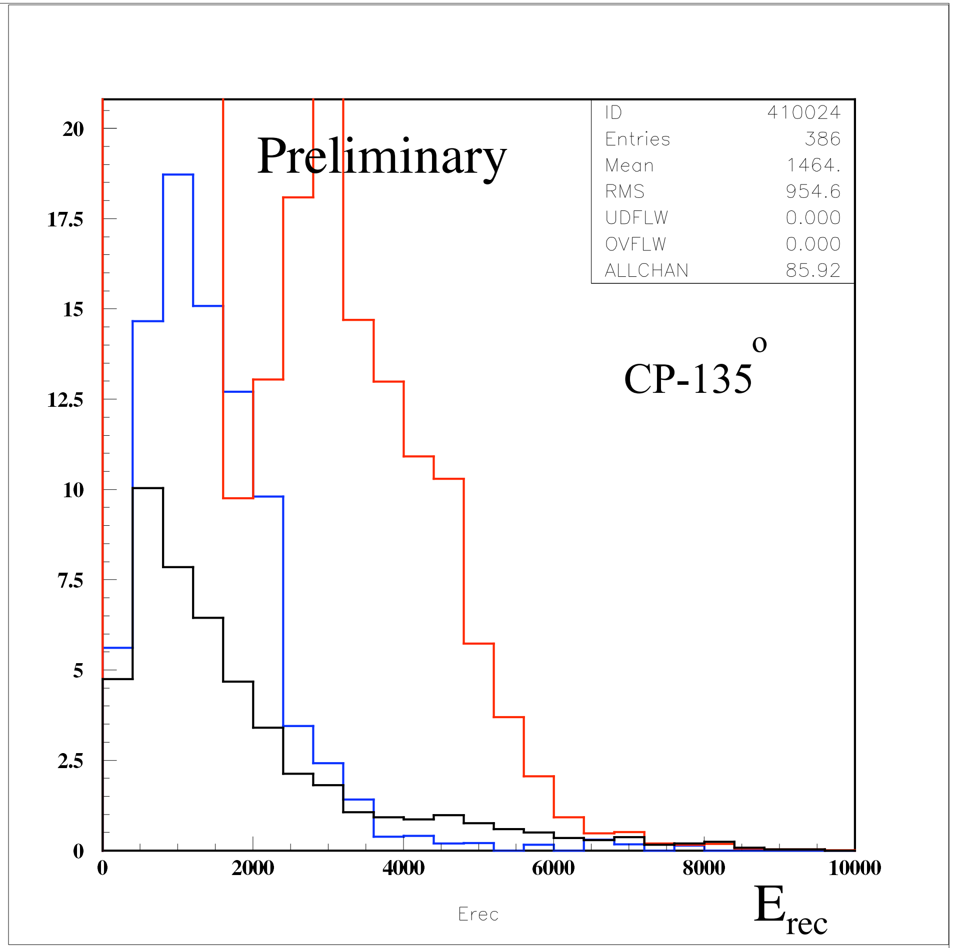
Singnal and Background ν_e QE for signal, all ν_μ and ν_e NC/nonQE CC for bkg

- Effect of cut on likelihood

Δlikelihood cut (~50% signal retained)



Δlikelihood cut (~50% signal retained)



Note new background estimate!

Signal/Background

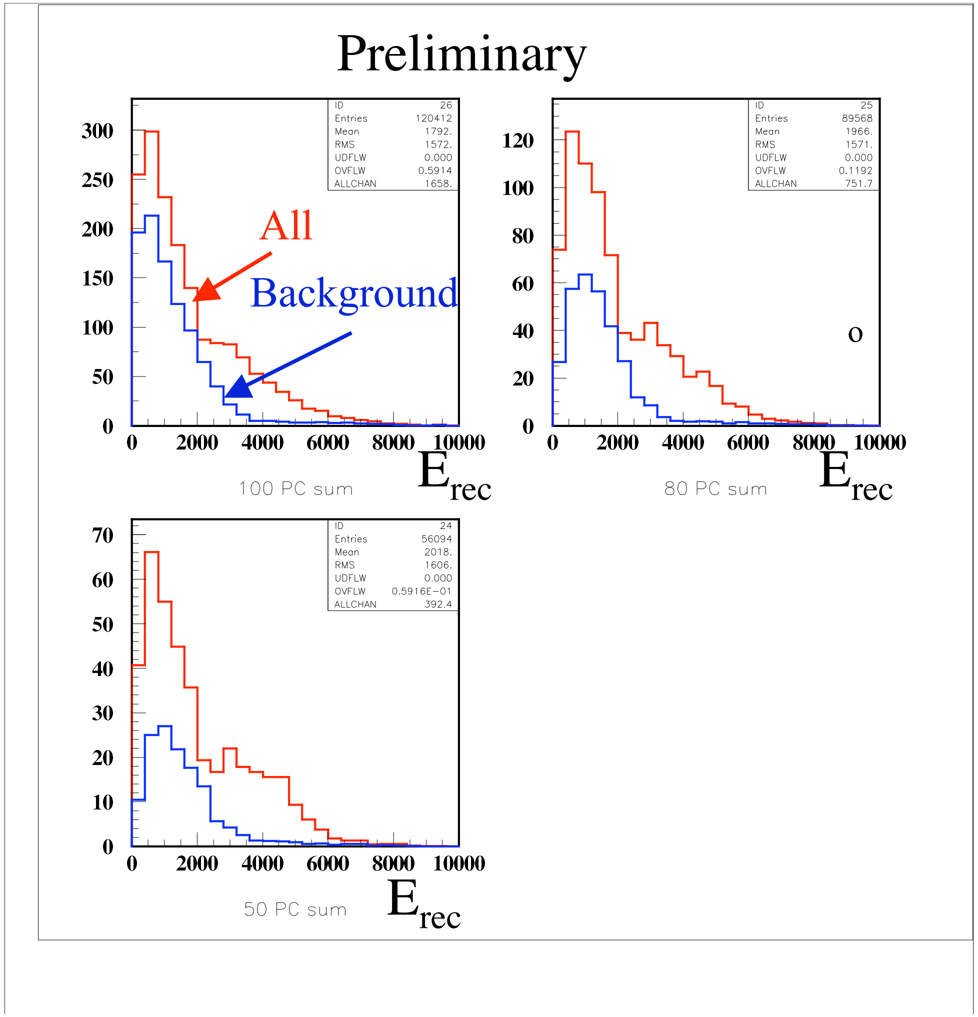
Singnal and Background

- Effect of cut on likelihood

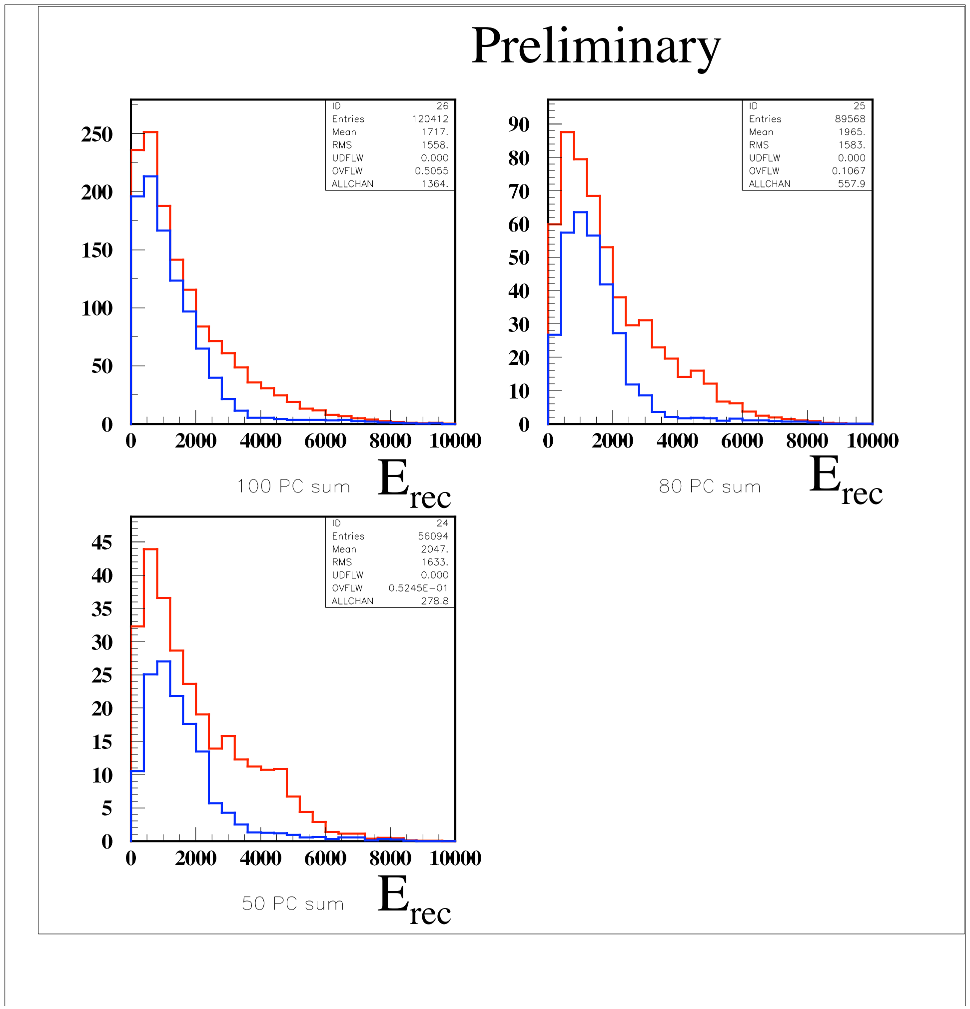
ν_e CC for signal

all ν_μ , ν_e NC , ν_e beam for bkg

CP +45°



CP-45°



Note new background estimate!

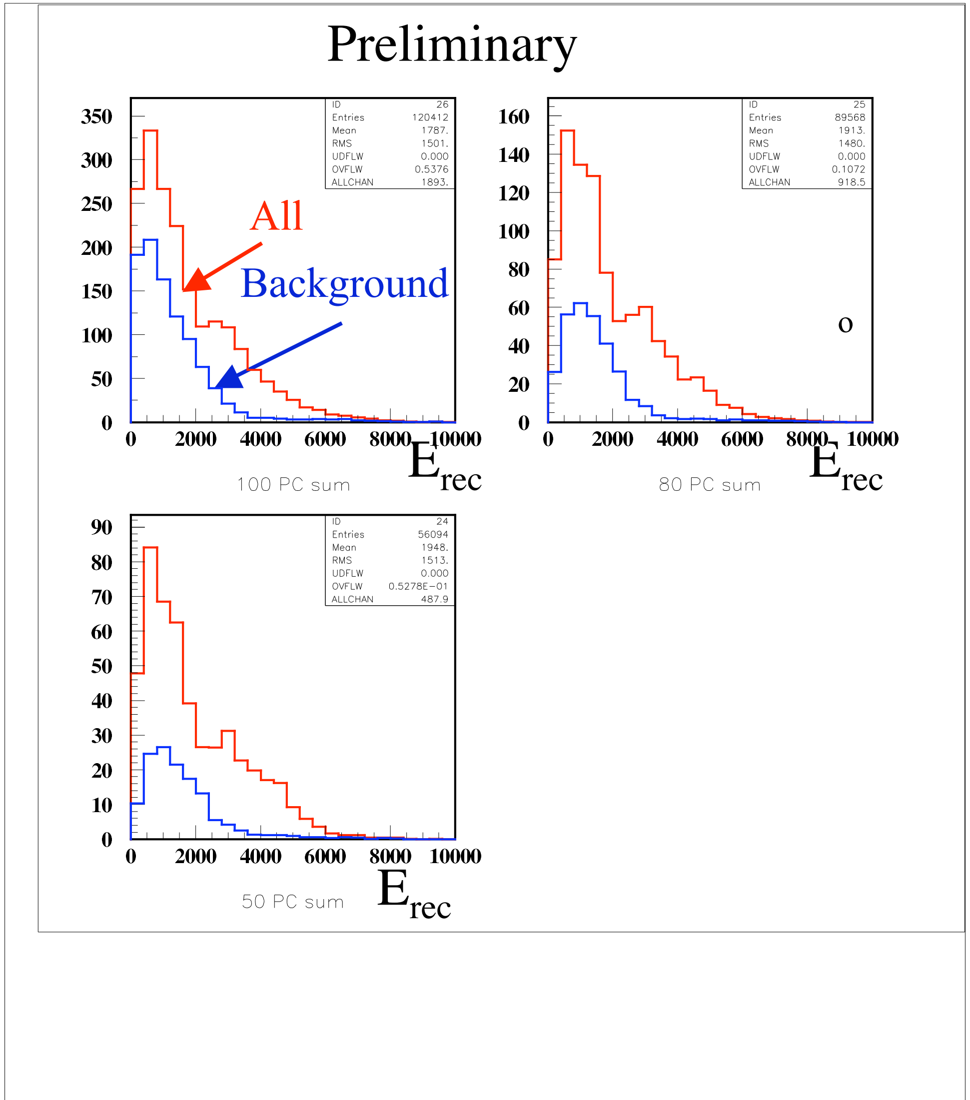
Signal/Background

Singnal and Background

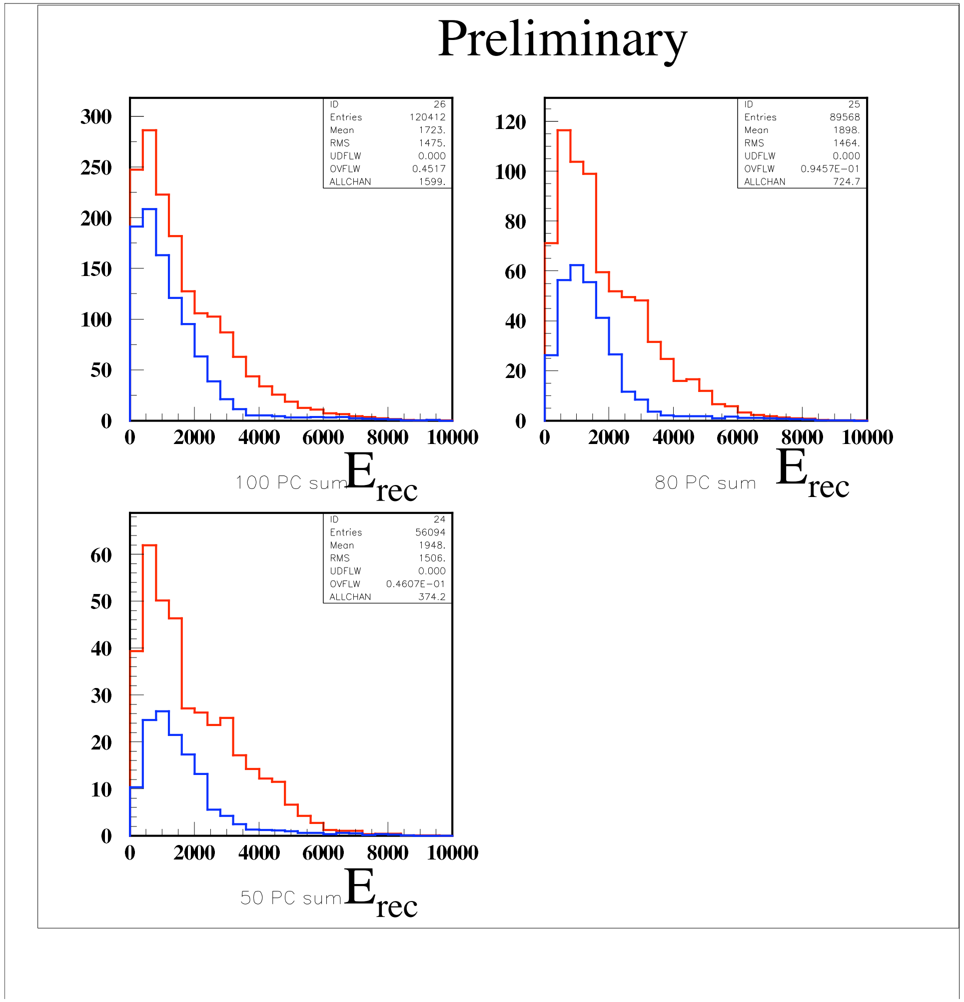
- Effect of cut on likelihood

ν_e CC for signal
all ν_μ,ν_e NC, ν_e beam for bkg

CP -135°



CP-135°



_ S/N issue

NEW background estimation!

Issues

Summary of BNL superbeam@UNO

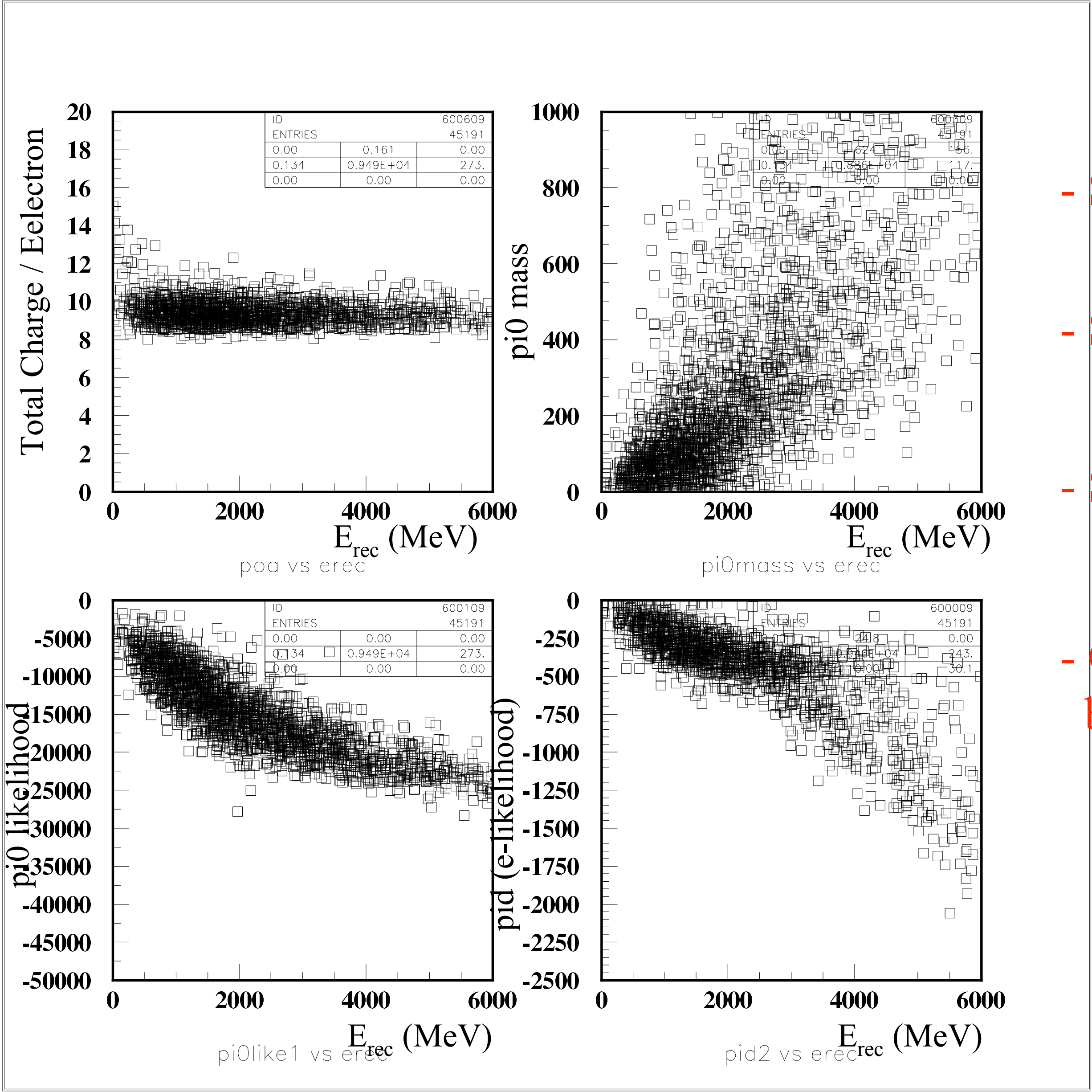
CP phase	Signal	Bkg	Effic	Signal	Bkg	Beam ν_e
0^o	ν_e QE	ν_μ all, ν_e NC/nonQECC	50%	130 179	137 88	49
-135^o	ν_e QE	ν_μ all, ν_e NC/nonQECC	50%	174 240	151 86	49
$+135^o$	ν_e QE	ν_μ all, ν_e NC/nonQECC	50%	258 353	181 86	49
-45^o	ν_e QE	ν_μ all, ν_e NC/nonQECC	50%	103 142	127 86	49
$+45^o$	ν_e QE	ν_μ all, ν_e NC/nonQECC	100%	365 689	1152 834	141 141
	ν_e CC	ν_μ all, ν_e NC	80%	289 439	376 227	86 86
			50%	187 256	157 88	49 49

We are really in business!

Correlation issue

Correlations with E_{rec}

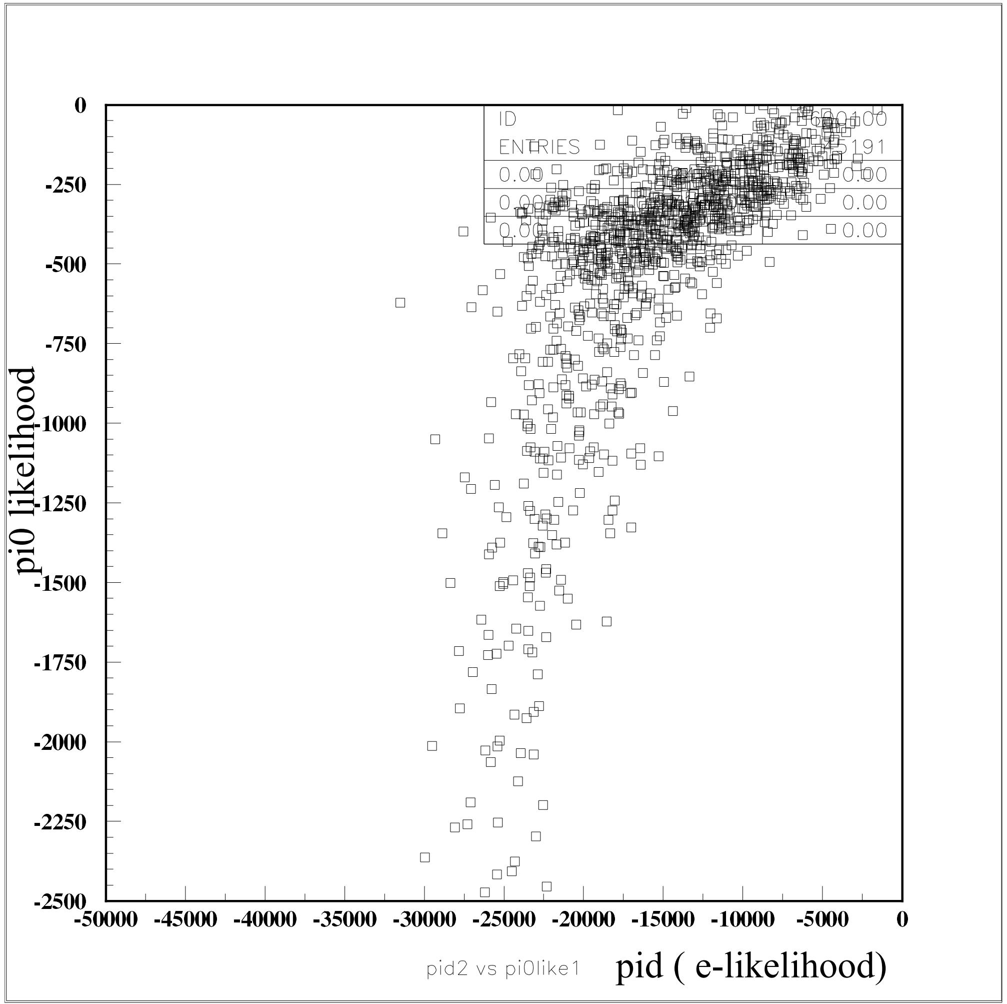
Source of energy dependence of likelihood



- Some variables are independent of energy
- Some variables have positive correlation with energy
- Some variables have negative correlation with energy
- Correlations with energy may bring correlations among variables

_ Correlation issue

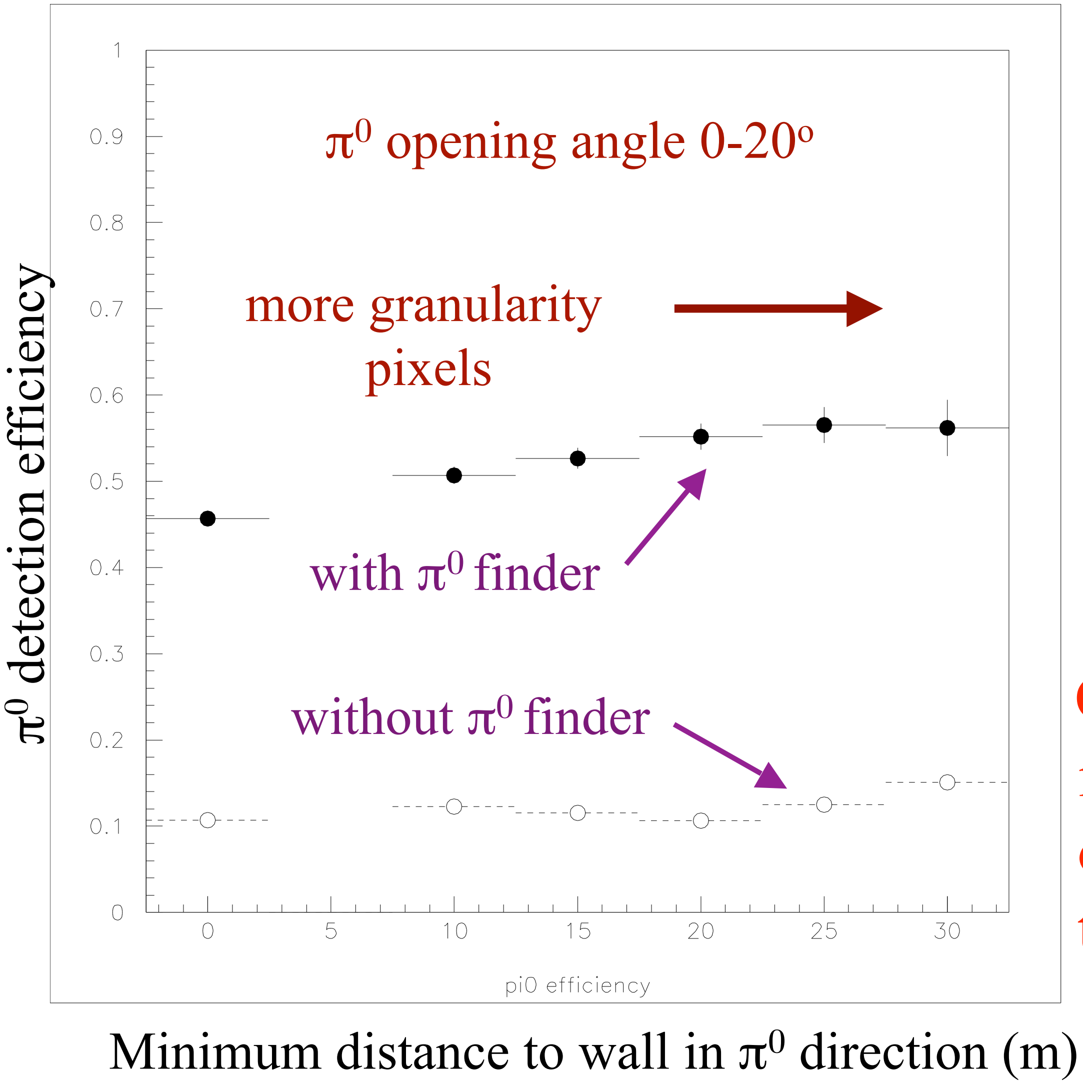
- Correlations among variables used for likelihood



Granularity/π^0 efficiency issues

- Expected improvement with UNO?

Compared with SK size detector



- For smaller π^0 opening angle finer granularity needed
- π^0 efficiency improves when min. distance increases (up to 20%)
- See power of π^0 finder

One issue I never mentioned before is that 2/3 of UNO volume is covered only 10% by PMTs and that we need to check the detector performance wit 10% PMT coverage

Future prospect/plans

- Number of variables used needs to be reduced
- Correlations may have to be reduced as much as possible or properly treated

Some special technique to be employed such as Principal Component Analysis(?)

- Some variables associated with some pattern recognition such as pi0-likelihood and e-likelihood seem quite useful

More sophisticated pattern recognition algorithm is highly desirable and possible

- This kind of analysis can give an insight to optimize neutrino beam spectrum

Studies on sensitivities to oscillation parameters should be done

Careful study of the source of background and the associated neutrino energy is needed

What granularity UNO needs to have?

_ Conclusions

- Realistic MC simulation studies have been performed for BNL very long baseline with a water Cherenkov detector and it was found that BNL VLBL combined with UNO can DO GREAT JOB

- It was demonstrated that there is some room to improve SN ratio by reducing the background level while keeping a reasonable signal detection effciency with current available software

  - We need to do similar analysis using a MC package that simulates the UNO baseline design (2 x 10% + 40% coverage and size)
  - We may need further improvement of algorithm/software, which is possible
  - Detailed studies on sensitivity on oscillation parameters needed
  - A larger detector such as UNO has an advantage over a smaller detector such as SK (See my talk in Minneapolis, April,2004)

Need a detailed Monte Carlo package for UNO!